TRANSPORTATION SAFETY REGULATORY BULLETIN

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-DISCUSSION OF SHIPPING URANIUM

NOTE FROM THE EDITOR

There have been a number of press articles lately highlighting the fact that DOE's uranium inventory has trace amounts of fission products and transuranics. This should not be a surprise to the transportation community, and does not pose any significant problems from a transportation standpoint. However, there does seem to be some confusion about which A_2 values to apply and shipping description for this material, so I have chosen that as this issue's special topic.

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TYPES OF URANIUM

For transportation purposes, uranium comes in three basic types: natural, enriched and depleted. The definitions for these three materials are found in 49 CFR 173.403. The delineation between the three is predicated upon the weight percentage of ^{235}U present. There is also a definition for "unirradiated uranium", which is based upon the amount of plutonium and fission products present per gram of ^{235}U. DOE has significant inventories of all of these types of uranium in various forms including metal, oxide, UF_4, UF_6, and uranyl nitrate. For simplicity, this discussion will deal specifically with oxides and metal only. UF_6 and other uranium compounds/concentrates may be addressed in future bulletins.

URANIUM AT DOE FACILITIES

Natural uranium consists primarily of ^{238}U, ^{235}U, ^{234}U and the isotopes in their respective decay chains. Once chemical extraction has taken place, in addition to the ^{238}U, ^{235}U and ^{234}U, there will be ^{234}Th, ^{231}Th, ^{230}Th, and ^{231m}Pa present. Other decay products will not have had time to "grow in" to a significant extent. Additionally, the gaseous diffusion enrichment process concentrates the percentage of ^{234}U (a daughter of ^{238}U).

Beginning in the early 1950's, a small percentage of feed material into DOE gaseous diffusion plants was reclaimed from reprocessed spent reactor fuel. This feed material contained trace amounts of transuranics (Np, Pu, Am), fission products (^{99}Tc, ^{60}Co, ^{137}Cs) and ^{236}U. Once this feed was introduced, the cascades were contaminated, and consequently, all resultant uranium will carry these contaminants to some extent.

In addition to using reclaimed uranium, DOE also blends different enrichments. For example, 20% enriched material might be blended with 2% material for a resultant enrichment of 11%. This will result in a distribution of nuclides slightly different than if there had been a straight enrichment from natural U.

URANIUM UNDER DOT REGULATIONS

Traditionally, DOT has treated uranium as either a low-specific activity material (U-nat. and U-dep.) or as fissile (U-enr.). Additionally, uranium can be considered for excepted packaging under the limited quantity, or manufactured items sections of the regulations. For "pristine" or non-recycled U, a shipper would merely use the A_2 value of unlimited for depleted uranium and simply determine whether it would be more economical to ship it as either LSA-I or as an excepted package, limited quantity shipment. The same would be true for material enriched less than 5% that also met the fissile excepted criteria.

Recycled uranium is not just depleted or enriched uranium, but it is a mixture of uranium, fission products and transuranics. Despite their low concentrations, the contaminants cannot be ignored and the shipping determination must be made using the mixture equation found in 173.433. The unlimited A_2 value cannot be applied because the A_2 value was developed with the assumption that the material was produced from natural uranium enriched by gaseous diffusion. This fact is more clearly stated in the footnotes to the A_1/A_2 table found in the international regulations (IAEA and ICAO).

EXAMPLE SHIPMENT DETERMINATIONS

Let's look at a couple of examples and see how the contaminants found in recycled uranium can impact a shipment:

<u>Scenario 1</u>

Consider the following analytical data for a gaseous diffusion plant waste stream:

Nuclide	pCi/g	TBq/g
U	3411	1.2621E-10
^{235}U	.39% wt	.39% wt
^{234m}Pa	1096	4.0552E-11
^{237}Np	2621	9.6977E-11
^{137}Cs	2.59	9.583E-14
^{134}Cs	0.22	9.11E-15
^{60}Co	0.21	7.77E-15
^{241}Am	1548	1.7276E-11
^{232}Th	0.61	2.257E-14
^{230}Th	29.98	1.1093E-12
^{228}Th	4.04	1.4948E-13
^{239}Pu	48.11	1.7801E-12
^{238}Pu	82.36	3.0473E-12
^{99}Tc	271,681.4	1.0052E-8

From this data, we see that we have depleted U (0.39% wt ^{235}U), and also natural thorium (^{232}Th). Decay products in the uranium chain are ^{234m}Pa from ^{238}U and ^{230}Th from ^{234}U. The ^{228}Th is a daughter of ^{232}Th. That leaves the following fission products: ^{137}Cs, ^{134}Cs, ^{60}Co, and ^{99}Tc, and transuranics: ^{237}Np, ^{241}Am, ^{239}Pu, and ^{238}Pu.

The material to be shipped is 332 kg of compacted PPE, rags, and plastic and metal, all within a single package. If we were shipping "pristine" depleted U, we could apply the unlimited A_2 value, then it would be shipper's choice as to whether it would be more economical to offer the shipment as a limited quantity under 173.421 or as LSA-I. Since we have a mixture, the unlimited A_2 value may not be applied, but we must instead use the equation found in 173.433(d)(2) to determine how the material may be offered.

Additionally, since there is the presence of fissile nuclides (^{238}Pu and ^{239}Pu), we will have to make a determination for qualifying the material as fissile excepted. Based upon the analytical data and the net weight of my material, I determine that I have 100 MBq of ^{239}Pu and 1.01 MBq of ^{238}Pu. Comparing this with the respective specific activities of each plutonium isotope, I determine that I have less than one gram total of fissile nuclides and will therefore qualify as fissile excepted.

Turning our attention now to the possibility of either limited quantity or LSA material, using the unity equation in 173.433(d)(2), I find that the ^{99}Tc and transuranics are too high to allow for shipping as a limited quantity. The LSA-I category is also not an option, as this material does not meet any of the criteria for that category. However, the unity equation shows that this material will easily meet LSA-II criteria.

We can also determine that we do not have an RQ, so our shipping description would be:

> "Radioactive material, LSA,n.o.s., 7, UN2912, U dep, ^{237}Np, ^{241}Am, ^{239}Pu, 3.5 GBq LSA-II, fissile excepted, exclusive use shipment."

I chose to list the U dep for clarity, but technically, under 173.433(f), only the transuranics would have to be shown. As you can see, small concentrations of TRU can impact the shipping choices and descriptions. The good news is that in the majority of cases, the option of using an excepted packaging under the LSA/SCO section will still be available.

Scenario 2

Now let's look at a situation involving LEU (1.63%) material. I have two drums with surface contaminated metal generated as part of a building cleanup project. Drum #1 contains 30.87 kg of metal, and Drum #2 contains 128.94 kg of metal. A sample from the waste stream that produced the surface contamination has been analyzed and is as follows:

Nuclide	pCi/g
^{234}U	20,608.9
^{235}U	1249.7
^{236}U	577.1
^{238}U	11,735.7
^{234}Th	16,729.9
^{237}Np	133.7
^{238}Pu	1.2
$^{239/240}Pu$	1.2
^{99}Tc	58,402.9

Now comes the tricky part—how much of the metal is contaminated? We can't just take the net weight of the metal and multiply by the concentration to get total activity per drum, as we will be adding in a lot of clean mass to our calculation. The project engineer has made a reasoned assumption (partially based upon initial survey data for the project) that 40% of the metal is contaminated. Based upon that, Drum #1 has 15.42 kg of contaminated metal , and Drum #2 has 51.53 kg of contaminated metal.

Following the procedure discussed in Scenario 1, we determine that Drum #1 has 8.92 g of fissile nuclides and Drum #2 has 29.82 g. Therefore, Drum #2 must be offered as a fissile material shipment. For Drum #1, either limited quantity or SCO would be desirable. Applying the mixture equation, we find that indeed, the limited quantity activity levels are not exceeded for Drum #1. To offer this drum as an SCO shipment would require more data in order to evaluate the contaminated metal against the SCO contamination limits.

OTHER QUESTIONS RELATED TO URANIUM

How do I use the table in 173.434 for reclaimed U?

49 CFR 173.434 lists activity-mass values for uranium and natural thorium. The values in this table for uranium were calculated for material produced by natural uranium in the gaseous diffusion process. It should also be noted that specific activity increases with enrichment but does so in a non-linear fashion (i.e., you cannot extrapolate between values). The values in the table are rounded-up values derived from the equation:

$$\text{Specific Activity} = (0.4 + 0.38E + 0.0034E^2) \times 10^{-6}\ \text{Ci/g},$$

where E is the enrichment.

The uranium values in 173.434 do not reflect accurate values for enriched or blended material from reclaimed U, however the values can be used for approximation. They will be "in the ballpark" for transportation purposes. If more precise values are needed, they can be determined analytically.

What uranium daughters can be "rolled up" with the parent nuclide?

In determining which daughters do not have to be treated as part of a mixture, the regulations say that those with half-lives of 10 days or less may be considered as a single nuclide and the values for the parent nuclide are the ones that are applied. For the ^{238}U chain, the short lived daughters of ^{234}Th are ^{234m}Pa and ^{234}Pa. In the ^{235}U chain, ^{231}Th is the daughter of ^{235}U, with a half-life of about 26 hours.